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INSTRUMENTATION AND SPACE RESEARCH DIVISION

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FINAL REPORT

P-4

Plasma Radio Wave Source Mechanism and Propagation Study for the Voyager Uranus Data Analysis Program

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Submitted by:

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PROJECT SUMMARY

The purpose of this project was to carry out a comprehensive program of investigation of the radio wave data obtained by the Planetary Radio Astronomy (PRA) instrument on board the Voyager spacecraft during the Uranus encounter. To do this we have utilized data analysis, ray tracing, and numerical analysis for non-linear wave growth stability calculations. We have investigated the source location and generation mechanisms for nightside broad-banded smooth radio emission and broad-banded bursty radio emission. We have also studied dayside narrow-banded bursty radio emission and the so-called "dayside source" which is most probably O-mode emission. Our studies at Uranus directly led us to suggest a possible explanation for reported observations at Jupiter. This final report includes reprints of papers which have appeared in refereed journals and abstracts of oral presentations. We also include an abstract of a paper which has been submitted for publication, and titles of papers which are currently in preparation and will be submitted soon.

A brief summary of some of the scientific accomplishments of this project follows:

- 1) We have extended the cyclotron maser theory to explain observations of fundamental O-mode and second harmonic X-mode in regions where $\omega_{pe} \leq 0.2 \Omega_{ce}$ (ω_{pe} is the electron plasma frequency and Ω_{ce} is the gyrofrequency). We find that the energy of the auroral electrons can play a significant role in determining the dominant wave mode. For electron energies less than about 2 keV, both O-mode and second harmonic emission can dominate over fundamental X-mode.
- 2) We find that the characteristics of the nightside smooth broad-banded radio emission are consistent with fundamental X-mode emission due to the cyclotron maser instability. In addition, the source region appears to be extended in longitude compared to previously reported studies which did not consider refractive effects.
- 3) We find that for large wave normal angles the source region of the nightside broad-banded bursty radio emission is distinct from the source region of the broad-banded smooth emission. These results are contrary to the results of others who have not accounted for refractive effects. We speculate that either the plasma distribution or the source mechanism in the source region is distinct from that which generates the broad-banded smooth emission.
- 4) We find that the "dayside source" is consistent with fundamental O-mode emission from source regions along field lines with footprints near the north magnetic pole. Sources of nightside broad-banded smooth emission are believed to exist along the same field lines, and thus the free energy source is likely to be electrons with energies of a few keV.
- 5) We find that for $\omega_{pe} < \Omega_{ce}$, anisotropic electron beams or gyrating electron beams can directly excite broad-banded electromagnetic radiation. This emission can be bursty, consistent with observations of the Uranus broad-banded bursty emission.
- 6) We find that characteristics of the narrow-banded smooth radio emission observed on the dayside of Uranus with a peak flux near 60 kHz are consistent with either fundamental

gyroemission or second harmonic gyroemission due to the cyclotron maser instability. Second harmonic emission is consistent with the theory mentioned in (1) above. The source region for either fundamental or second harmonic emission is probably the magnetic equator.

7) We have used the results summarized in (1) and (6) above and applied the ray tracing code developed for the UDAP program to decametric emissions at Jupiter. We find that Jovian decametric emissions are consistent with a source within 20° of the instantaneous Io flux tube. We further suggest that second harmonic emission may explain many observations that previously were thought due to a substantial ($\sim 70^\circ$) lag of the source field line behind the instantaneous Io flux tube.

8) We have modified the ray tracing code to analyze whistler mode propagation very near the resonance cone. The recent discovery of lightning at Uranus suggests that whistlers may exist in the magnetosphere of Uranus, but none have been reported. The code was applied to whistlers observed at Neptune and the large dispersions observed were attributed to propagation near the resonance cone over large distances of the magnetosphere.

9) We have modified our ray tracing code to account for various emission lobe profiles at the source. This, combined with high resolution spectral information, has allowed us to refine our determination of the source region of the nightside broad-banded smooth radio emission. We are currently preparing a paper to compare our results with recently reported UV observations of Uranus.

10) We have used the modifications described in (9) above to also examine the source region of dayside narrow-banded bursty radio emission. We are currently preparing a paper presenting the results.

Included in this report are the first page of reprints of all the published papers and an abstract of a submitted paper.

THE FOLLOWING PAPERS HAVE BEEN PUBLISHED AS A RESULT OF THIS PROJECT:

Wong, H. K., D. Krauss-Varban, and C. S. Wu, "On the role of the energy of suprathermal electrons in the generation of auroral kilometric radiation", J. Geophys. Res., 94, 5327, 1989.

Menietti, J. D., H. K. Wong, D. A. Wah, and C. S. Lin, "Source region of the smooth high-frequency nightside Uranus kilometric radiation: A ray-tracing study", J. Geophys. Res., 95, 51, 1990.

Curran, D. B., J. D. Menietti, and H. K. Wong, "Ray tracing of broadband bursty radio emissions from Uranus", Geophys. Res. Lett., 17, 109, 1990.

Menietti, J. D. and D. B. Curran, "The source region of O-mode radio emissions from the dayside of Uranus", J. Geophys. Res., 95, 15263, 1990.

Wong, H. K. and M. L. Goldstein, "A mechanism for bursty radio emission in planetary magnetospheres", Geophys. Res. Lett., 17, 2229, 1990.

Menietti, J. D. and D. B. Curran, "Possible Second Harmonic Gyroemission at Uranus", J. Geophys. Res., 95, 20959, 1990.

Menietti, J. D. and D. B. Curran, "Instantaneous Io Flux Tube as the Source of Jovian DAM: Possible Second Harmonic Emissions", J. Geophys. Res., 95, 21273, 1990.

PAPERS SUBMITTED TO JOURNALS:

Menietti, J. D., D. Tsintikidis, D. A. Gurnett, and D. B. Curran, "Modeling of Whistler Ray Paths in the Magnetosphere of Neptune", submitted to the Journal of Geophysical Research, 1991.

PAPERS IN PREPARATION:

Curran, D. B. and J. D. Menietti, "The source region and possible generation mechanisms for Uranus dayside narrow-banded bursty radio emission".

J. D. Menietti, D. B. Curran, and S. Gulkis, "Model calculations of the source region of Uranus nightside broad-banded radio emission: Comparison with UV observations"

We also include in this report abstracts of orally presented papers at the following national and international meetings:

The Neil Brice Memorial Symposium on Magnetospheres of the Outer Planets held October 10-13, 1988 at the Max Planck Institut fur Aeronomie, West Germany.

The American Astronomical Association's Division of Planetary Science Meeting held on Oct. 31-Nov. 3, 1988 in Austin, Texas.

The Spring Meeting of the American Geophysical Union (AGU) held May 7-12, 1989 in Baltimore, MD.

The Fall Meeting of the AGU held Dec. 4-8, 1989 in San Francisco, CA.

The National Radio Science Meeting (URSI) held Jan. 3-5, 1990 in Boulder, CO.

The Spring Meeting of the AGU held May 29-June 1, 1990 in Baltimore, MD.

The Fred Scarf Memorial Symposium on Magnetospheres of the Outer Planets held August 20-24, 1990 in Annapolis, MD.